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Effectual and Rapid Aggregate Data Collection Using Wireless Sensor Network

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***Abstract*— Theis work aimed to collect the data fast from wireless sensor network under the many-to-one communication known as converge cast. Converge cast, collection of data from a set of sensor towards a mobile sink over a tree based routing topology. Combining scheduling with the transmission power control will reduce the effort of interference. The power can be saving by using beacon signal. Efficiency of different channel assignment method and interference model has been compared, and proposes schemes Construct Bounded degree minimal radius spanning tree and capacitated minimal spanning tree, and show significant improvement in scheduling performance over different deployment that enhance data collection rate for both aggregated and raw data. To better benefit from the sink's mobility, scheduling movement patterns of a mobile sink to visit some special places in a deployed, in order to minimize data gathering time.**

Keywords: Convergecast; Scheduling; Spanning tree; Mobile sink.

I. INTRODUCTION

Wireless sensor networks (WSNs) are formed from sensor nodes with limited resources that are deployed to detect physical phenomena. These nodes generate data and operate in a multi-hop fashion to relay data from other nodes. Converge cast, many to one stream of data from a group of sources to a mobile sink over a tree-based routing topology, is a basic operation in wireless sensor networks (WSNs) [1]. In many applications, it is essential to provide a assurance on the delivery time as well as increase the rate of such data collection. Two types of data collection.

- Aggregated Convergecast
- Raw-data Convergecast

A. Aggregated Convergecast

Aggregated convergecast where packets are accumulated at each hop. It can be used for *continuous data collection*. It is relevant when a well-built spatial correlation exists data. Permafrost [3] monitoring requires periodic and fast delivery over long periods of time which comes under the category of aggregated converge cast [2].

B. Raw-data Convergecast

Raw-data Convergecast where packets are individually relayed toward the sink[2].It can be used for one shot data collection. It is germane when every sensor reading is equally important, or the correlation is minimal. These two types resemble to two tremendous cases. No data compression happens in the raw-data converge cast, on the other hand full data compression happens in the aggregated converge cast [4]. Time Division Multiple Access (TDMA) are better fit for fast data collection, it eliminate collisions and retransmissions. The problem of constructing conflict-free (interference-free) TDMA schedules even under the simple graph-based interference model has been proved to be NP-complete and design polynomial-time heuristics to minimize the schedule length for both types of converge cast [2].

We start by identifying the primary limiting factors of fast data collection, which are:

- *Interference* in the wireless medium,
- *Half-duplex* transceivers on the sensor nodes
- *Topology* of the network.

Then, we explore a number of different techniques that provide a hierarchy of successive improvements, the simplest among which is an interference-aware, minimum-length TDMA scheduling that enables spatial reuse. To achieve further improvement, we combine transmission power control with scheduling, and use multiple frequency channels to enable more concurrent transmissions [2]. Even though different techniques can be used to collect the data fastly from wsn. We have some interference, scheduling problem and packet delay can be occurs.

To avoid this problems and to efficiency collect the data from sensor network constructing the *Bounded Degree Minimum Radius Spanning Tree Protocol* (BDMRSTP)and deploy some mobile sinks in the spanning tree to collect the data from group of nodes. Scheduling can be done by using three methods.

- Joint Frequency Time Slot Scheduling (JFTSS) used for link level
- Receiver-Based Channel Assignment

  (RBCA) used for node level
- Tree-Based Multichannel Protocol

  (TMCP) used for cluster level [2]

Finally the data should be scheduled and send to the destination.

II. Related Work

To minimize the number of time slots required to complete Converge cast for aggregated data [5] and raw data [6]. Most of the existing algorithms aim to maximize the number of concurrent transmissions and enable spatial reuse by devising strategies to eliminate interference[7].construct capacitated minimal spanning tree can reduce the schedule length by 50%and number of time slots in multi-channel scheduling . This factor improvement for raw-data converge cast [2]. Spanning trees can be used satisfy constraints on node degrees, diameter, or total cost. Minimum-Degree Spanning Tree problem, where the goal is to construct a spanning tree such that its maximum node degree is minimized, is NP-hard on general graphs [9]. In [10], Singh and Lau consider the Minimum-Bounded-Degree Spanning Tree problem where , given a degree bound on each vertex, they find a spanning tree of optimal cost with each degree exceeding its bound by at most one. The Minimum-Diameter Spanning Tree problem is to construct a spanning tree such that the tree diameter, defined as the longest hop distance between any pair of nodes, is minimized. On Euclidean graphs, this problem is solved in polynomial time, and the result extends to any complete graph whose edge weights satisfy a distance metric [11]. Bounded-Degree Minimum Diameter Spanning Tree problem, where the goal is to minimize the tree diameter subject to a degree constraint. The first bicriteria approximation algorithm on general graphs is proposed by Ravi et al. [12], which runs in time O mN log N. construct the Bounded degree minimum radius spanning tree protocol show significant improvement in scheduling performance over different deployment that enhance data collection rate for aggregated data.[8]. It can improve the throughput-delay trade off for aggregated data collection in sensor networks.[7]. Mobile sinks, such as animals or vehicles equipped with radio devices, are sent into a field and communicate directly with sensor nodes, resulting in shorter data transmission paths and reduced energy consumption [14]. It is more promising for energy efficient data gathering [15]. Deploying some mobile sink in particular places in the tree to minimize the data gathering time and packet delay.[13].

III. Wireless Sensor Network Model

Wireless Sensor Networks, which are responsible for sensing as well as for the first stages of the processing hierarchy.

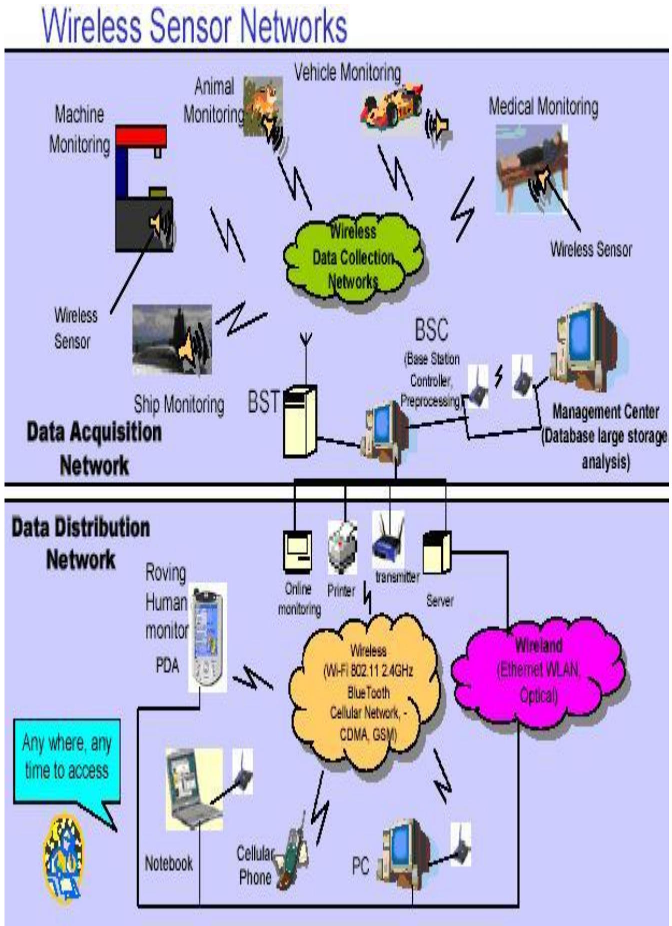
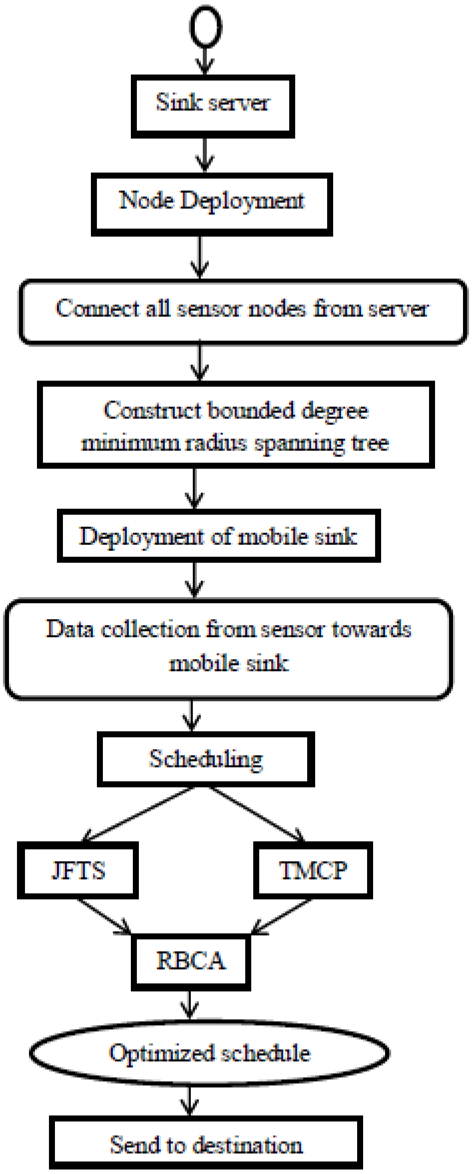


Figure 1. Wireless Sensor Network [16]

The figure shows the complexity of wireless sensor networks, which generally consist of a data acquisition network and a data distribution network, monitored and controlled by a management center [17].

The study of wireless sensor networks is challenging in that it requires an enormous breadth of knowledge from an enormous variety of disciplines. It outline communication networks, wireless sensor networks and smart sensors, physical transduction principles, commercially available wireless sensor systems, self-organization, signal processing and decision-making, and finally some concepts for home automation [17].

A. Dataflow Diagram



IV. RAW DATA COLLECTION

The data collection rate often no longer remains limited by interference but by the topology of the network. Thus, in the final step, we construct network topologies with specific properties that help in further enhancing the rate. Our primary conclusion is that, constructing capacitated minimal spanning tree can reduce the schedule length by 50% in multi-channel scheduling and a factor of improvement for raw-data converge cast, compared to single channel TDMA scheduling on minimum-hop routing trees.

Algorithm1 Capacitated Minimal spanning tree [19]

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1. Input: $G(V;E),s$
2. Initialize:
3. $B \leftarrow$ roots of top sub trees //the branches
4. $T \leftarrow \{s\} \cup B$
5. $\forall i \in V$, $GS(i) \leftarrow$ unconnected neighbours of I at further hops
6. $\forall b \in B, W(b) \leftarrow 1$
8. while $h \neq max\_hop\_count$ do
9. $N_h \leftarrow$ unconnected nodes at hop distance
10. Connectnodes $N_h^{|}$ that have a single potential parent :$T \leftarrow T \cup N_h^{|}$
11. Update $Nh \leftarrow Nh \setminus N^{|}h$
12. Sort Nh in non-increasing order of $|GS|$
13. for all $i \in Nh$ do
14. for all $b \in B$ to which i can connect do
15. Construct $SS(i; b)$
16. end for
17. Connect i to b for which $W(b) + |SS(i,b)|$ is minimum
18. Update $GS(i)$ and $W(b)$
19. $T \leftarrow T \cup \{i\} \cup SS(i,b)$
20. end for
21. $h \leftarrow h+1$
22. end while

The CMST problem, which is known to be NP-complete, is to determine a minimum-hop spanning tree in a vertex weighted graph such that the weight of every sub tree linked to the root does not exceed a prescribed capacity [19]. Algorithm 1, based on the greedy scheme presented by Dai and Han [20], which solves a variant of the CMST problem by searching for routing trees with an equal number of nodes on each branch. We augment their scheme with a new set of rules and grow the tree hop by hop outward from the sink. We assume that the nodes know their minimum-hop counts to sink.

V. AGGREGATED CONVERGECAST

Data aggregation is a commonly used technique in WSN that can eliminate redundancy and minimize the number of transmissions, thus saving energy and improving network lifetime[8]. Aggregation can be performed in many ways such as by suppressing duplicate messages; using data compression and packet merging techniques; or taking advantage of the correlation in the sensor readings. We consider continuous monitoring applications where perfect aggregation is possible, i.e., each node is capable of aggregating all the packets received from its children as well as that generated by itself into a single packet before transmitting to its parent. The size of aggregated data transmitted by each node is constant and does not depend on the size of the raw sensor readings.[2]

A. Aggregated data collection

The aim of aggregated data collection is that eliminates redundant data transmission and enhances the lifetime of energy in wireless sensor network [21]. Together data must be processed by sensor to reduce transmission responsibility before they are transmitted to the base station or sink. This pattern argument with a new set of rules and grow the tree hop by hop outwards from the sink. To assume that the nodes know their minimum-hop counts to sink.

B. Bounded Degree Minimum Radius Spanning Tree Protocol (BDMRSTP)

By constructing Bounded Degree Minimum Radius Spanning Tree Protocol (BDMRSTP) show significant improvement in scheduling performance over different deployment that enhance data collection rate for aggregated data [2]. First of all Spanning Tree Protocol(STP)[22] can implement by using Ethernet bridges and switches to construct a loop free shortest path network using Spanning tree algorithm. Shortest path is based on cumulative link costs. Link costs are based on the speed of the link.

TABLE I. LINK COST TABLE

Link Speed	Cost(Revised IEEE Spec)	Cost(Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

The Spanning-Tree Protocol establishes a root node, called the root bridge. It constructs a topology that has one path for reaching every network node. The resulting tree originates from the root bridge. Redundant links that are not part of the shortest path tree are blocked. Because certain paths are blocked, a loop free topology is possible. Data frames received on blocked links are dropped. Because certain paths are blocked, a loop free topology is possible. The Spanning-Tree Protocol requires network devices to exchange messages to help form a loop-free logical topology. These topology are called Bridge Protocol Data Units (BPDUs).In BPDU Links that will cause a loop are put into a blocking state. BPDUs continue to be received on blocked ports. This ensures that if an active path or device fails, a new spanning tree can be calculated. BPDUs contain enough information so that all switches can do the following: Select a single switch that will act as the root of the spanning tree, Calculate the shortest path from itself to the root switch, Designate one of the switches as the closest one to the root, for each LAN segment. This bridge is called the designated switch. It handles all communication from that LAN towards the root bridge. Choose one of its ports as its root port, for each non-root switch. This is the interface that gives the best path to the root switch. Select ports that are part of the spanning tree called designated ports. Non-designated ports are blocked.STP States, States initially set, later modified by STP. Time is required for (BPDU) protocol information to propagate throughout a switched network. Topology changes in one part of a network are not instantly known in other parts of the network. There is propagation delay [22]. A switch should not change a port state from inactive (Blocking) to active (Forwarding) immediately, as this may cause data loops. Each port on a switch that is using the Spanning-Tree Protocol has one of five states,

- Blocking
- Listening
- Learning
- Forwarding
- Disabled

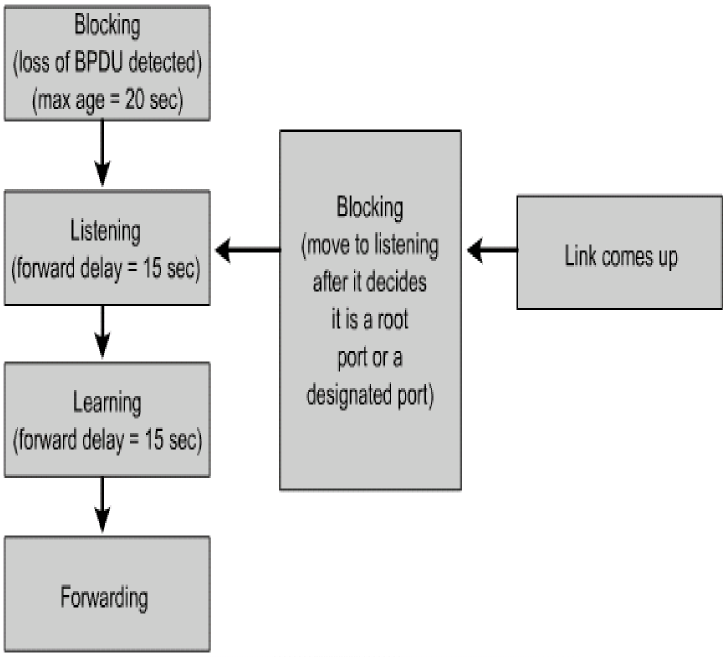

Figure 2. Spanning Tree protocol states

C. Blocking State

Ports can only receive BPDUs, Data frames are discarded and no addresses can be learned[22]. It may take up to 20 seconds to change from this state.

D. Listening State

Switches determine if there are any other paths to the root bridge. The path that is not the least cost path to the root bridge goes back to the blocked state.[23] BPDUs are still processed. User data is not being forwarded and MAC addresses are not being learned. The listening period is called the forward delay and lasts for 15 seconds

E. Learning State

User data is not forwarded, but MAC addresses are learned from any traffic that is seen. The learning state lasts for 15 seconds and is also called the forward delay. BPDUs are still processed.[22]

F. Forwarding state

User data is forwarded and MAC addresses continue to be learned.BPDUs are still processed.

G. Disabled State

It can occur when an administrator shuts down the port or the port fails.

Main function of the Spanning Tree Protocol (STP) is to allow redundant switched/bridged paths without suffering the effects of loops in the network. Because Fault tolerance is achieved by redundancy [23]. It can also eliminate single point of failure, If a path or device fails, the redundant path or device can take over the tasks of the failed path or device.STP executes an algorithm called Spanning Tree Algorithm

(STA)[22].It chooses a reference point, called a root bridge, and then determines the available paths to that reference point. If more than two paths exist, STA picks the best path and blocks the rest. Bounded Degree Minimum Radius Spanning Tree Algorithm (BDMRSTA) is used to achieve the goal to minimize the tree diameter subject to a degree constraint.

Algorithm 2.Bounded Degree Minimum Radius Spanning Tree [7]

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1. **Input:** G = (V,E); sink s; degree bound $\Delta * \geq 2$
2. **Output:** BDMRST T of G
3. Tessellate the 2-D region into hexagonal grid cells, each of side length R/2.
4. Associate each node to a unique cell whose center is closest to the node.
5. **Phase 1: Backbone Tree**
6. All cells are unmarked.
7. Initialize T_B: $V_B \leftarrow \{s\}$, $E_B \leftarrow \varphi$, mark cell of s.
8. Choose one local root arbitrarily from each non-empty cell; let $R = \{r_1, \ldots, r_n\}$ be the set of local roots.
9. $Q \neq \varphi$;
10. ENQUEUE (Q, s);
11. **While** $Q \neq \varphi$ **do**
12. u← DEQUEUE(Q);
13. **for all** unmarked cells c_j adjacent to u **do**
14. $r_j \leftarrow$ local root in c_j ;
15. **if** $d(u, r_j) \leq R$ **then**
16. $V_B \leftarrow V_B \cup \{r_j\}$;
17. $E_B \leftarrow E_B \cup \{(u, r_j)\}$;
18. Mark c_j;
19. ENQUEUE(Q, r_j);
20. **else if** $d(u, r_j) > R$ and ∃helper node w **then**
21. $V_B \leftarrow V_B \cup \{r_j, w\}$;
22. $E_B \leftarrow E_B \cup \{(r_j ,w_k), (w_k, u)\}$;
23. Mark c_j ;
24. ENQUEUE(Q, r_j);
25. **else if** $d(u, r_j) > R$ and ∃helper edge w **then**
26. $V_B \leftarrow V_B \cup \{r_j, w_k, w_k^{|}\}$;
27. $E_B \leftarrow E_B \cup \{(rj ,w_k), (w_k, w_k^{|}), (w_k^{|} , u)\}$;
28. Mark c_j ;
29. ENQUEUE (Q, r_j);
30. **end if**
31. **end for**
32. **end while**
33. **Phase 2: Local Spanning Tree**
34. **for all** non-empty cells c_j **do**
35. $r_j \leftarrow$ local root in c_j ;
36. Let $V_j = \{v_1 \ldots v_{nj}\}$ be the set of not yet connected nodes in c_j (V_j induces a complete graph).
37. Construct local spanning tree T_j of minimum radius with nodes in V_j such that no node exceeds degree.
38. **end for**
39. **return** $T = T_B \cup \{T_j\}$.

Phase 1—Backbone Tree Construction:

1) In the opening, all the cells are unmarked. We initialize T_B with the sink s and mark its cell c_s.
2) Choose one local root arbitrarily from each nonempty cell. Let this set of nodes be $R=\{r_1 \ldots r_n\}$
3) Consider those unmarked adjacent cells $\{c_j\}$ of s that intersect a circle of radius R centered at s , and for which one of the following conditions is met.
a) Local root r_j in cell c_j is a direct neighbour of s .b) Local root r_j in cell c_j is not a direct neighbour of s .but there exists some other node w_k, called a *helpernode*, that is a common neighbour of both s and r_j .
c) Local root r_j in cell c_j is neither a direct neighbour of s nor is there any helper node, but there exists a *helper edge* $(w_k, w_k^{|})$,whose one end, say w_k , is incident in cell c_j and the other end $w_k^{|}$ in cell c_s.
4) For case a), connect r_j directly to s and mark its cell c_j. Update T_B by adding r_j to V_B , and the edge (r_j, s) to E_B .
5) For case b), connect r_j to s via the helper node. Mark c_j and update T_B by adding r_j and w_k to V_B, and the two edges (r_j,w_k) and (w_k,s) to E_B .
6) For case c), connect r_j to s via the helper edge. Mark c_j and update T_B by adding r_j,w_k and to $w_k^{|}$, and the three edges(r_j,w_k) , $(w_k, w_k^{|})$, and $(w_k^{|},s)$to E_B.
7) Consider, in BFS order, these marked cells $\{c_j\}$, and repeat steps 3–6 with node replaced by the corresponding local root in c_j .
8) Continue until all the local roots in R get connected. We implement the BFS processing of the local roots in a queue data structure.

Phase 2—Local Spanning Tree Construction

Consider the local root rj in cell cj . Let the set of nodes in cj that are not yet connected to the backbone tree be $Vj=\{v1\ldots\ldots vnj\} \subset V/VB$. Connect v1 to rj treating rj as its parent. Then, connect at most $\Delta * -1$ nodes (if those many exist) from Vjtov1 ; these constitute the direct neighbours of v1.Next, treating these direct neighbours as parents, connect at most$\Delta * -1$ nodes to each one of them, if those many exist. Continue this until there is no isolated node left in Vj, and repeat the procedure for each of the non empty cells. At the end of this phase, each cj contains a local spanning tree Tj rooted at rj, with each node (except the leaves and the last parent) having degree$\Delta *$. The overall spanning tree T is the union of the backbone tree TB and all the local spanning trees Tj.

VI. SINK MOBILITY

Sink mobility is one of the most comprehensive trends for information gathering in sensor networks. This way of

information gathering has a prominent role in balancing the energy consumption among sensor networks. The mobile sink traverses the entire network uploading the sensed data from cluster heads in time driven scenarios.

The mobile sink trajectory is planned such that all heads require no multi-hop relays to reach the mobile sink. Sink mobility as an efficient solution for data gathering problem. In such networks the sink changes its position from time to time , traverses the network, and collects sensed data from nearby nodes while moving.

Therefore, employing a mobile device to collect data can reduce the effects of the hotspots problem, balance energy consumption among sensor nodes, and thereby prolong the network lifetime to a great extent [25,26].

The path planning for a mobile sink was formulated as the mobile element scheduling (MES) problem based on the assumption that a mobile element visits each sensor node to collect data in wsn. It will achieve the goal to minimize the data gathering time.

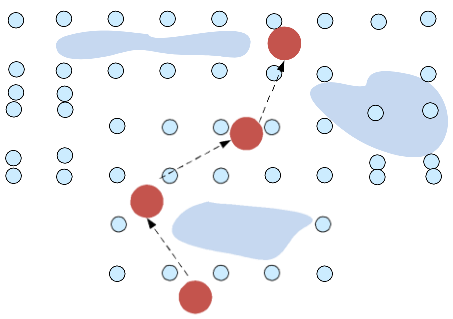

Figure 3. Data gathering

Figure 3.Data gathering with one mobile sink: large solid dots indicate the mobile sink's trail points, and sensor nodes maintain trail references as logical coordinates. Shaded areas stand for obstacles.

Algorithm 3. Mobile sink's strategy

1: /*——Initialization——*/
2: msg.seqN←0;
3: msg.hopC←0;
4: Announces step size parameter K
5: /*——Moving strategies——*/
6: **while** Not get enough data **or** Not timeout **do**
7: Move to next trail point;
8: msg.seqN←msg.seqN+1;
9: Stop for a very short time to broadcast trail message;
10: Concurrently listen for data report packets;
11: **end while**
12: End data gathering process and exit

A trail message from a mobile sink contains a sequence number (*msg.seqN*) and a hop count (*msg.hopC*) to the sink. The time interval between a mobile sink stops at one trail point and arrives at the next trail point is called one *"move"*. There are multiple moves during a data gathering round. The tasks of a mobile sink is summarized in Algorithm 3.[13]

VII. ASSIGNMENT OF TIMESLOTS

Given the lower bound $\Delta(T)$ on the schedule length in the absence of interfering links, we now present a time slot assignment scheme in Algorithm1, called BFSTIMESLOTASSIGNMENT, that achieves this bound.

Algorithm 4: *Bfs time slot assignment*

1. Input: T =(V , ET)
2. while ET_= φ do
3. e← next edge from ET in BFS order
4. Assign minimum time slot t to edge e respecting adjacency and interfering constraints
5. ET← ET \ {e}
6. end while

THEOREM 1: *If all the interfering links are eliminated, the schedule length for aggregated Convergecast achieved by* S TIMESLOTASSIGNMENT *is the minimum, i.e.,* $\Delta(T)$.

In each iteration of BFS-TIMESLOTASSIGNMENT (lines 2-6), an edge *e* is chosen in the Breadth First Search(BFS) order starting from any node, and is assigned the minimum time slot that is different from all its adjacent edges respecting interfering constraints. Note that, since we evaluate the performance of this algorithm also for the case when the interfering links are present, we check for the corresponding constraint in line 4; however, when interference is eliminated this check is redundant. The algorithm runs in $O(|ET|2)$ time and minimizes the schedule length when there are no interfering links, as proved in Theorem 1[2].

VIII. SCHEDULING METHODS:

A. Joint Frequency Time Slot Scheduling (JFTSS)

Joint Frequency Time Slot Scheduling (JFTSS) enables a greedy joint solution for maximal time schedule. A maximal schedule is that which meets the adjacency and interfering constraints, and no further links can be scheduled for concurrent transmissions on any time slot. A comparative study of single channel and multichannel system is discussed in [30].

JFTSS scheduling in a network starts from the link having highest number of packets for transmission. If the link loads are equal, the most constrained link is opted first. Initially algorithm has an empty schedule and links are sorted as per loads. The links having adjacency constraint with scheduled link are excluded from the list of link to be scheduled in a given time slot.

Only the link having non interfering constraint with scheduled link can be scheduled in the same slot and those having interfering constraint can be scheduled on different channels. If no more links are possible to be scheduled for a

given slot, the scheduler continues with scheduling in the next slot.

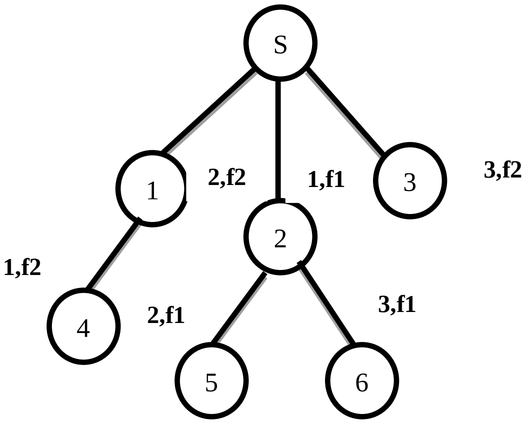

Figure 4. Joint Frequency Time Slot Scheduling

Figure 4.shows the same tree in Fig. 2(a) which is scheduled according to JFTSS to collect aggregated data. JFTSS starts with link(2,s) on frequency1(F1)and then schedules link(4,1)on the first slot on frequency 2 (F2).Then, links(5, 2)on frequency 1(F1) and (1, s)on frequency 2(F2)are scheduled on the second slot and(3,s)on frequency2(F2) are scheduled on the last slot. An advantage of JFTSS is that it is easy to incorporate the physical interference model; however, it is hard to have a distributed solution since the interference relationship between all the links must be known.[31]

B. *Tree based Multichannel Protocol(TMCP)*

Tree-based, multi-channel protocol for data collection applications. It divides the network into multiple sub trees and minimizes the intra tree interference by assigning different channels to the nodes residing on different branches starting from the top to the 020bottom of the tree Scheduled according to TMCP for aggregated data collection. The advantage of TMCP is that it is designed to support Converge cast traffic and does not require channel switching. Since all the nodes communicate on same channel, the contention inside branches is not resolved. Figure 5.the nodes on the leftmost branch are assigned frequency F1, second branch is assigned frequency F2, and the last branch is assigned frequency F3 and after the channel assignments, time slots are assigned to the nodes with the BFS-Time Slot Assignment algorithm.

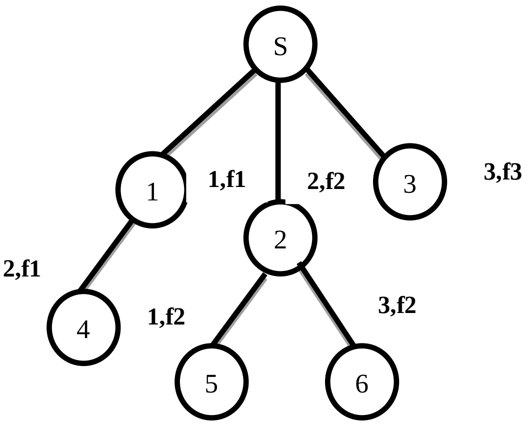

Figure 5. TMCP Scheduling

C. *Receiver-Based Channel Assignment (RBCA)*

In RBCA, the children of a common parent transmit on the same channel. Every node in the tree, therefore, operates on at most two channels, thus avoiding pair-wise, per-packet, channel negotiation overheads. The Capacitated Minimal spanning tree algorithm initially assigns the same channel to all the receivers. Then, for each receiver, it creates a set of interfering parents based on SINR thresholds and iteratively assigns the next available channel starting from the most interfered parent (the parent with the highest number of interfering links).[2]

In SINR-based physical model, The successful reception of a packet from *i* to *j* depends on the ratio between the received signal strength at *j* and the cumulative interference caused by all other concurrently transmitting nodes and the ambient noise level. Thus, a packet is received successfully at *j* if the signal-to-interference-plus-noise ratio, *SINRij*, is greater than a certain threshold β. However, due to adjacent channel overlaps, SINR values at the receivers may not always be high enough to tolerate interference, in which case the channels are assigned according to the ability of the transceivers to reject interference. We proved approximation factors for RBCA when used with greedy scheduling in [32].

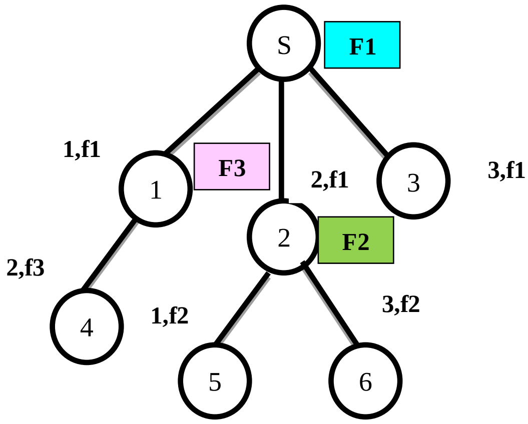

Figure 6. RBCA Scheduling

Initially all nodes are on frequency *F*1. RBCA starts with the most interfered parent, node 2 in this example, and assigns *F*2. Then it continues to assign *F*3 to node 3 as the second most interfered parent. Since all interfering parents are assigned different frequencies sink can receive on *F*1.

IX. CONCLUSION

The conclusion of this work is data can be collected fastly and efficiently from sensor node using mobile sink. The proposed algorithm bounded-degree minimum radius spanning tree can improve the throughput-delay tradeoff for aggregated data collection in sensor network. Thus the Future work is to improve the mobile sink to move freely in deployed area and use T-Hash chain to identify the hackers in the network.

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